EFFECTIVE USAGE OF DATA INTENSIVE SENSORS IN GRID ENVIRONMENT

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The scientists nowadays require and build complicated systems which help research in different fields of the science. The advance of the technologies on the other hand allows build of precise sensors which generate enormous data sets. The collected data should be stored and later on used by the scientists. The power of a single computer, even a super computer is not enough to store and process the collected data. To solve the problem the computing grid systems has emerged. They collect the power of many computers and present it as one, which can be easily used by the scientists. The article observes different ways of connecting and using the grid systems. The aim is to propose an optimal configuration considering the requirements of the data intensive sensors.

Keywords: sensors, grid systems, data replication algorithms

1. INTRODUCTION

Nowadays the fields of the science require large amounts of data to be stored and later on processed. The advance of the technology allows construction of complicated systems consisting of thousands sensors (see fig.1), which sometimes generate enormous data sets (an example is the data-intensive problem that arise in the high-energy physics experiments currently being developed at CERN (derived from the French Conseil Européen pour la Recherche Nucléaire), which will generate petabytes of scientific data by 2007) [1].

It is impossible for a single computer, even a super computer to handle these data. The computational grid system is the key to answer the problem of collecting, and efficient usage of the computing power [2].

The Grid approach is an important development in the discipline of computer science and engineering [3]. Since the grid system is collection of many organizations, and every organization has its own network, the grid system becomes a complicated connection of many networks. Optimizing the use of Grid resources is crucial, and to evaluate potential optimization strategies it is important to simulate them as realistically as possible before they are used on real Grids [4]. The article aims to represent and estimate (through simulation) the optimal usage of the grid system, regarding the network topology, task scheduling and data replication algorithms. Since every combination of algorithms and network topologies, could increase or decrease the system performance, it is essential to know which combination of algorithms is the most appropriate for the used network topology.

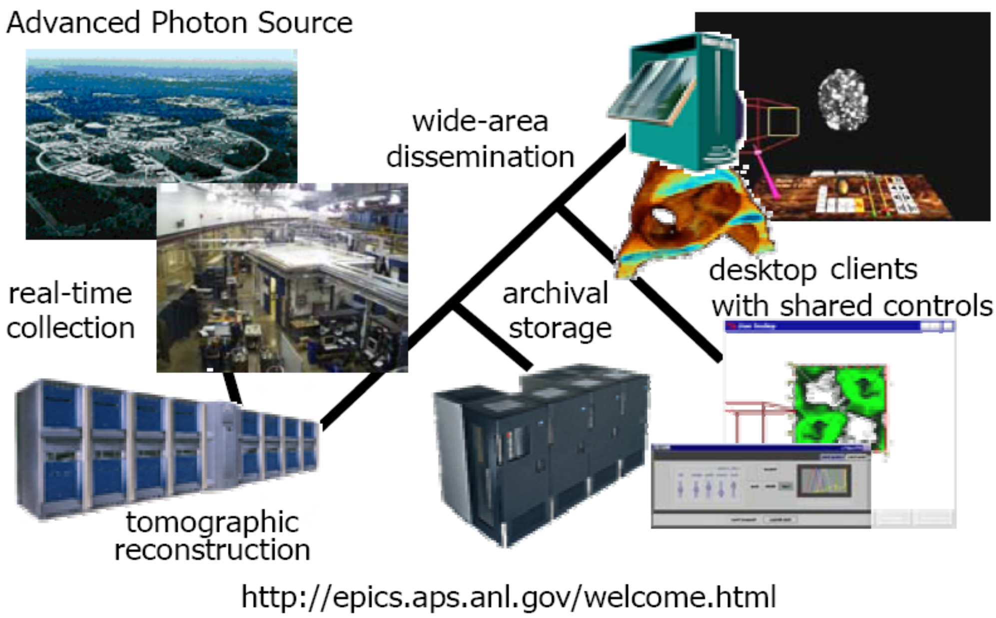

Fig.1: Intensive data sensors and computers data sets

For the reconstruction of the last and of the different grid environment configurations, it is used the grid simulator OptorSim which gives the opportunity to study and estimate the effective use of the grid system components like the network topology, the computing elements and the data storage elements. In a Grid computing environment, each site can contain several storage or/and computing elements. OptorSim takes a grid configuration and a replica optimizer algorithm as input and then runs a number of grid jobs using the given configuration.

2. SIMULATION ENVIRONMENT

Choosing the appropriate grid simulator is an important part of the study. Since the emerging of grid systems few grid simulators (BRITE, GridSim, MONARC, OptorSim) has been developed. The OptorSim gives the best opportunity to simulate and evaluate different network topologies, task scheduling and data replication algorithms. It is part of the European DataGrid (EDG) project, so different real grid systems configurations have been tested through OptorSim [5].

2.1. Choosing network topologies

Regarding the requirements for high network traffic (produced by the data generated from the data intensive sensors), few network topologies with high connectivity has been considered: Fully Connected, 2D-Mesh, Wraparound Mesh, 4D-Hypercube (see fig. 2).

The topologies showed on the figure 2 have different number of connected nodes. However in the simulation setup this number is one and the same for all network topologies. The fully connected network topology is the best choice for high network traffic (since every single node is connected to the others), but the number of connections increase quadratic with respect to the number of nodes which makes it difficult to implement.

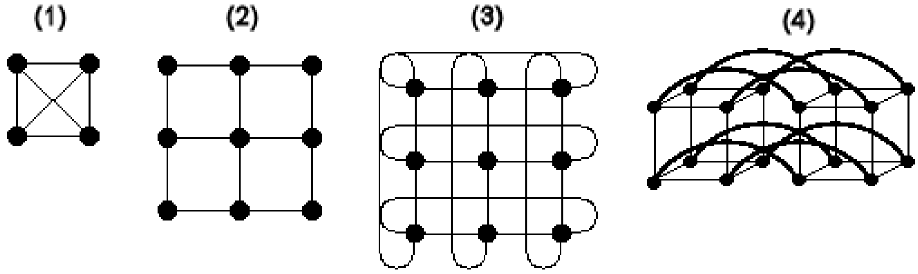

Fig. 2: Network topologies used in simulation – (1) Fully connected; (2) 2D-Mesh; (3) Wraparound Mesh; (4) 4D-Hypercube

2.2 Choosing task scheduling algorithms

The selected task scheduling algorithms are as follows:

- random – the grid resource broker schedules the task on random grid node
- shortest queue – the grid resource broker schedules the task on the grid node with the shortest job queue
- access cost – the grid resource broker schedules the task on the grid node with the minimal file access cost
- queue access cost – the grid resource broker schedules the task on the grid node where the file access cost for the job and for the selected grid node queue jobs is minimal

2.3. Choosing data replication algorithms

The data replication is used to decrease the network usage and increase the grid system productivity. The simulation process has been setup in two ways: with and without data replication algorithm. The aim is to show the importance of the data replication. The selected data replication algorithms are as follow:

- no replication – the grid system does not use data replication
- always replicate – always replicate files and delete the oldest

2.4. Evaluation metrics

The environment of OptorSim grid simulator defines the following evaluation metrics, which are later on used to evaluate the output of the simulation.

- mean job execution time – the total time to execute all jobs in the grid, divided by the number of completed jobs
- effective network usage – the higher value means higher network traffic
- CE (computing element) usage – the total computation power usage in the grid

3. SIMULATION SETUP

The OptorSim simulator represents the grid system as nodes and connections between them. A node consists of CE (Computing Elements) and SE (Storage Elements). The connections between nodes represent the network topology. The data intensive sensors require high network throughput which will require the whole network availability (no background traffic). The jobs processed by the grid system in the simulation are configured to require much more storage space than computing power. Every node in the grid can run any job. The grid system configuration is as follows:

- Number of nodes for network topologies: 2^{10} = 1024 (in 4D-Hypercube the number of edge nodes is 16 and each edge node has 64 fully connected internal nodes, which makes 1024 nodes)
- Storage element capacity per node: 200 GBytes
- Job size: 1000 GBytes separated in 500 files (2GBytes per file)
- Network speed for all nodes: 1Gbit

The master files (not replicated ones) for the job are random spread among the nodes of the grid system.

4. RESULTS

To estimate the best and the worst grid system configurations based on the examined: four task scheduling algorithms, four network topologies, and two data replication algorithms; all thirty two different grid system configurations were simulated and examined. Every single simulation configuration has been run ten times. This is needed because of the used "random" task scheduling algorithm, and random positioning of the job's master files on the grid nodes. The values used in the graphics below are RMS (Root Mean Square) values calculated by equation 1.

$$x_{\text{rms}} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} x_i^2}$$

Equation 1: RMS equation used in the calculations with N=10

As a whole the best performance (2855966 sec) gives the "fully connected" network topology with "queue access cost" task scheduling algorithm. For this network topology the grid system performance is not affected by the kind of the replication algorithm. In the real world for large number of nodes this topology is difficult to implement and other topologies are used.

As figure 3 shows (excluding the "fully connected" topology), the data replication algorithms have great influence of the grid performance. The difference in "mean job time" for grid configuration with and without data replication algorithm is about 37% (mean value of all topologies and task scheduling algorithms).

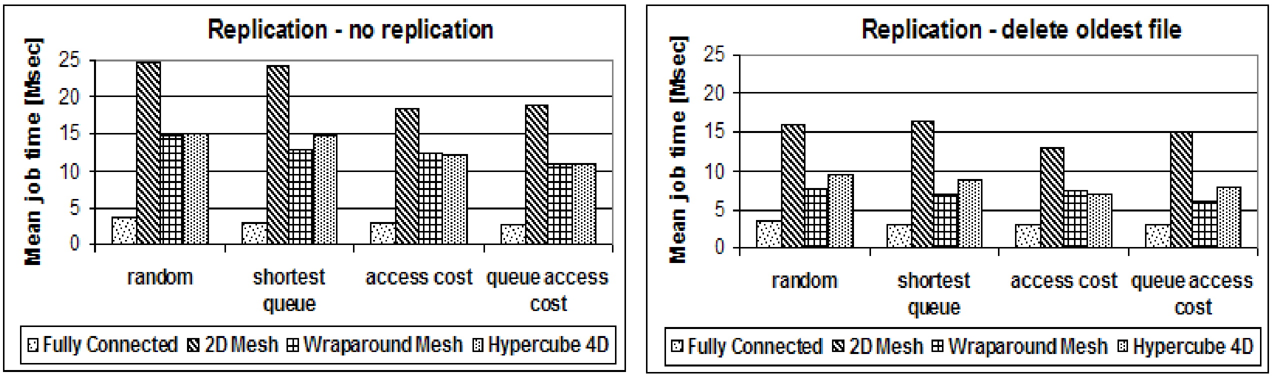

Fig. 3: Mean job times for the simulated grid system

The worst performance (24766246 sec) of the grid system is given by the "random" task scheduling algorithm without using data replication algorithm for 2D-Mesh network topology. The difference between the best and the worst configuration is 88.47 %.

The usage of the CE in the grid system is shown on figure 4. The best CE usage (83.75%) is presented by following configuration: task scheduling algorithm – shortest queue; network topology – fully connected.

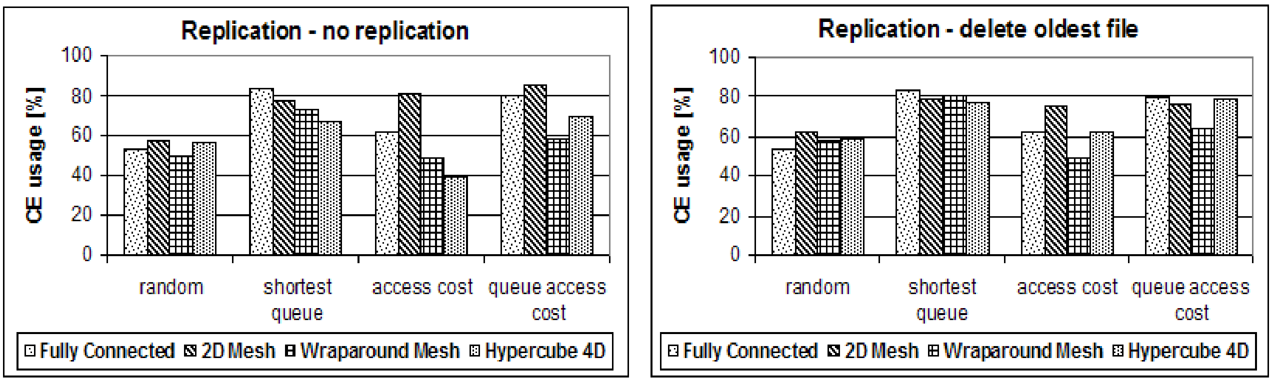

Fig. 4: CE usage for the simulated grid system

The network usage is given in percents on figure 5. For any task scheduling algorithm, regardless the data replication algorithm the efficient network usage is constant.

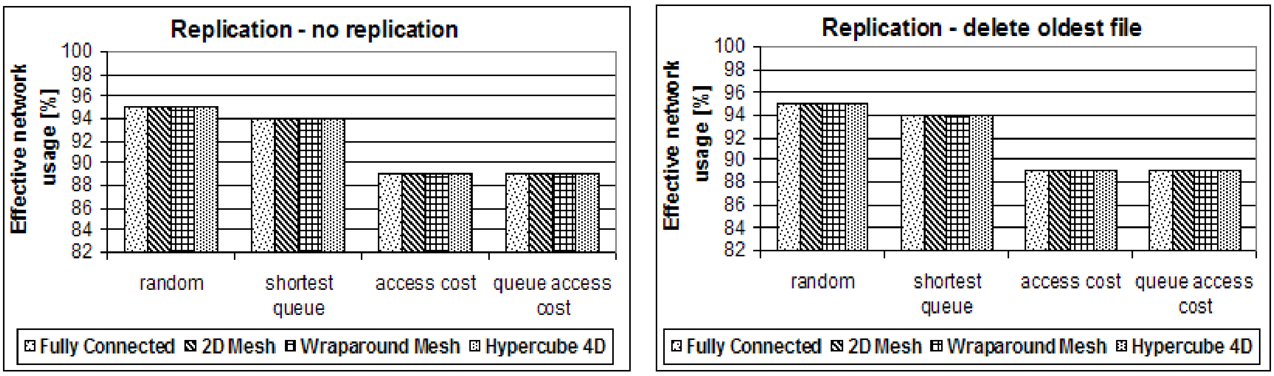

Fig. 5: Effective network usage for the simulated grid system

To achieve better grid system performance the "mean job time" is regarded. The table 1 shows examined the grid configurations sorted by "mean job time".

Network topology; Task scheduling algorithm	**Without replication [sec]**	**With replication [sec]**	**Network topology; Task scheduling algorithm**
Fully connected; queue access cost	2855966	2855966	Fully connected; queue access cost
2D-Mesh; access cost	18424672	13080199	2D-Mesh; access cost
Wraparound mesh; queue access cost	10813777	6156200	Wraparound mesh; queue access cost
4D-Hypercube; queue access cost	10803855	6978737	4D-Hypercube; access cost

Table 1: Sorted by "mean job time" grid configurations, less value means better performance.

5. CONCLUSION

To fulfill the requirements of the scientists for a powerful computer, accessible from any place and distributed among may organizations the computing grid systems have emerged. They can store and process enormous data sets generated by many data intensive sensors. To make an optimal usage of a grid system, the last should be carefully configured. Since the grid system is spread among different organizations and network topologies, the last in combination with task scheduling and data replication algorithms have great impact of the grid system performance. This impact was proved by modeling and simulating a data intensive task in a grid environment.

The results show that the difference between the best and the worst grid system configuration is around 88 %, which means that the optimal usage of the grid system greatly depends on its component's configuration and the nature of the executed computing tasks.

6. REFERENCES

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